REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
	Technical Papers	

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

8. PERFORMING ORGANIZATION REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20021018 029

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Leilani Richardson
Unclassified	Unclassified	Unclassified	A		19b. TELEPHONE NUMBER *(include area code)* (661) 275-5015

9 items enclosed

[redacted]

09

MEMORANDUM FOR PR (In-House Publication)

09 December 1999

FROM: PROI (TI) (STINFO)

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-1999-0248**
Hargus, W., "AFRL Hall Thruster Development" (BFI)

JANNAF Propulsion Meeting (Tucson, AZ, 14-16 Dec 1999) **(Statement A)**

AFRL
Hall Thruster Development

AFRL/PRRS Spacecraft Propulsion Branch
USAF Electric Propulsion Group

William Hargus

Tel: 661-275-6799

Fax: 661-275-5203

Email: william_hargus@ple.af.mil

AFRL Electric Propulsion Requirements

Air Force Missions (from AFSPC):

- Space-Based Radar
- Space Command
- On-Orbit Inspection

Low Power
P < 200 W

- Small Propulsion (10-200W)
- Micropropulsion (1-10W)

- Stationkeeping

Medium Power
0.5 to 1 kW Arcjets
1 to 5 kW Hall Thrusters

- Largely Commercial

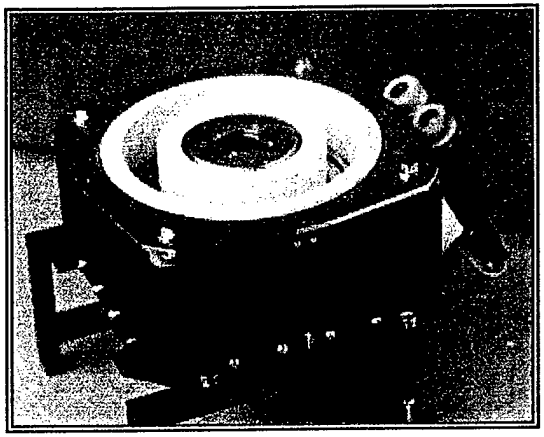
Arcjets: Primex
Resistojets: TRW, Primex
Hall: ARC, Busek, Primex, TRW
Ion Thrusters: Hughes

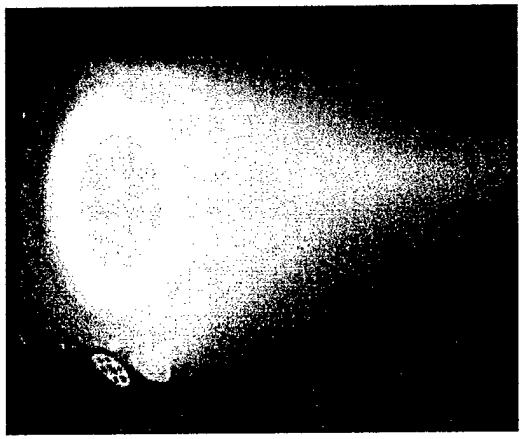
- Orbit Transfer
- On-Orbit Servicing

High Power
P > 10 kW

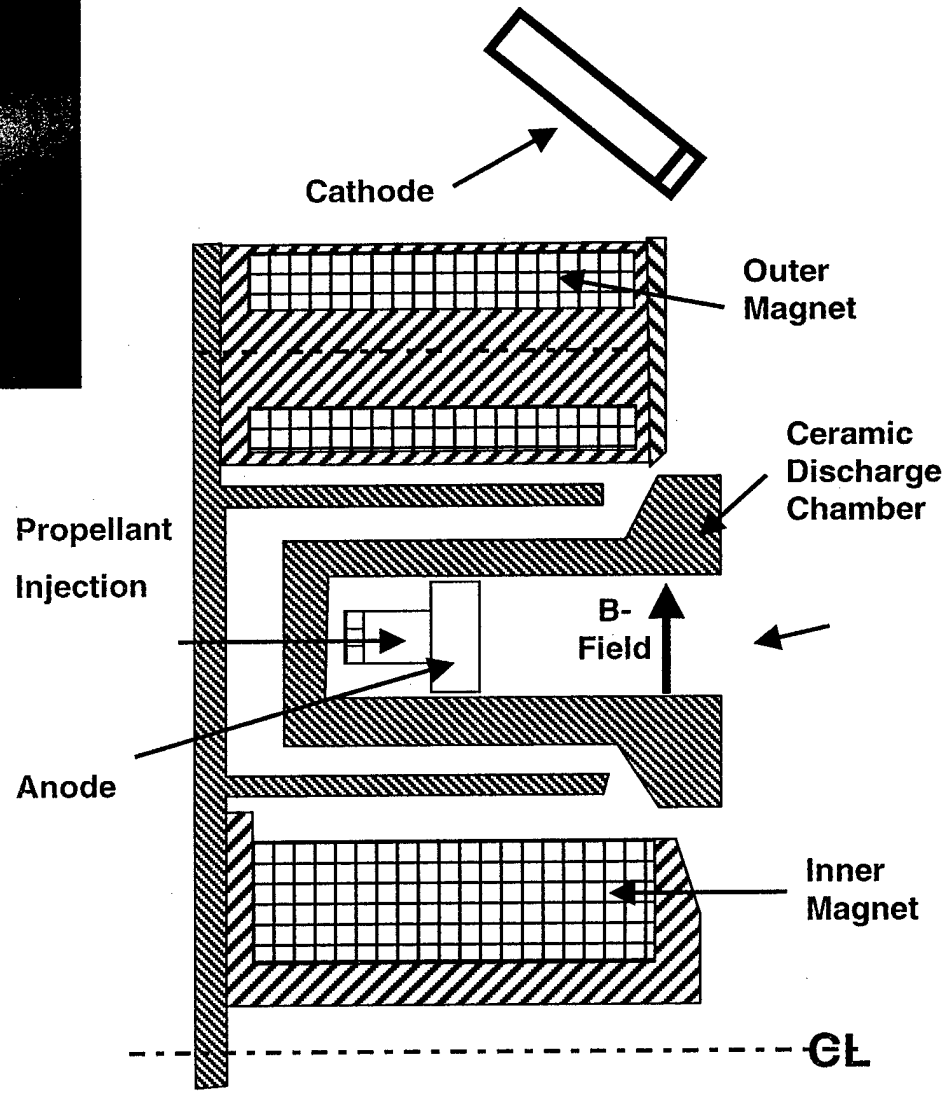
- Hall Thrusters

Hall Thruster System Operating Principles

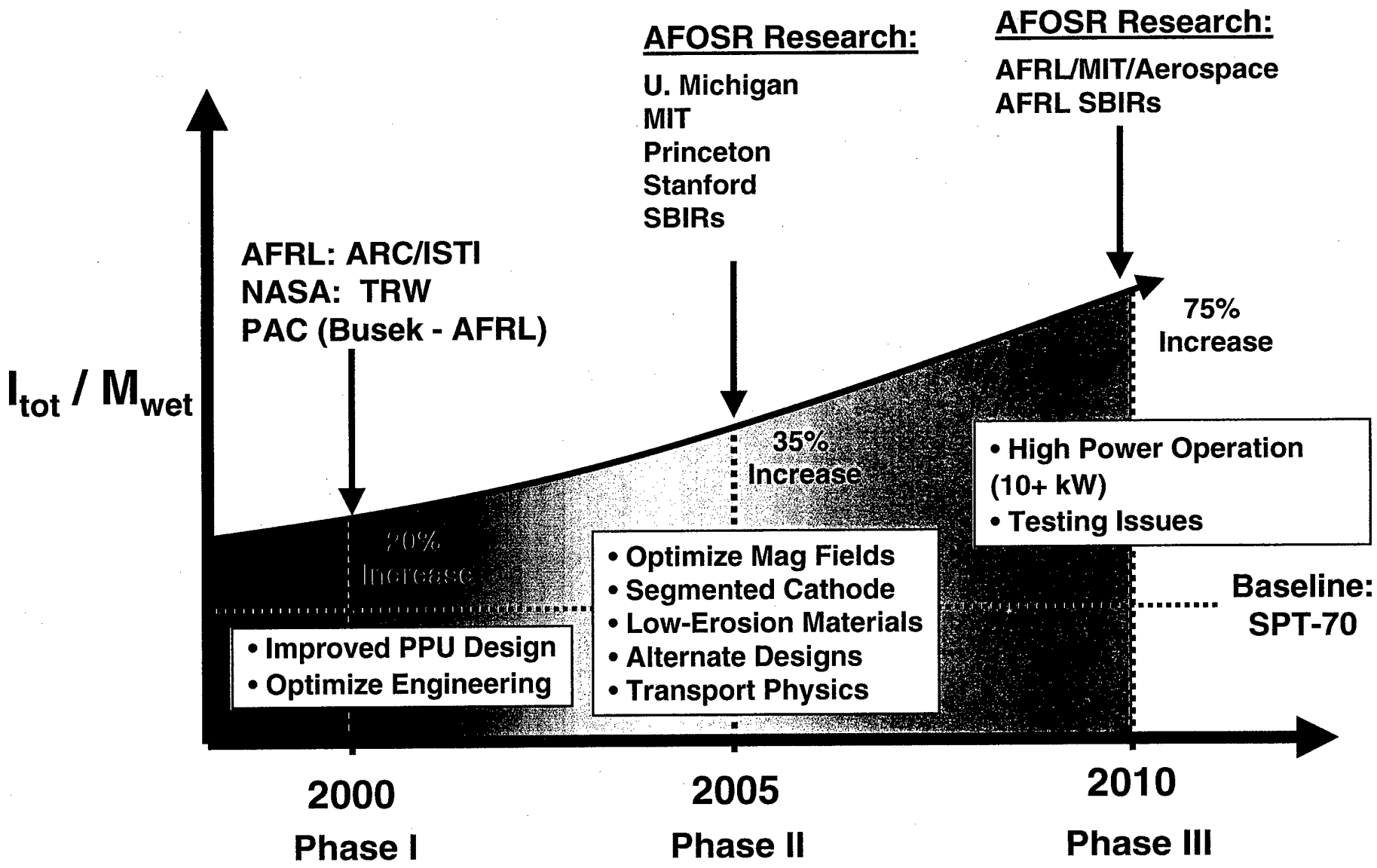




1. Electrons emitted from the cathode travel toward the anode.
2. Electrons are impeded in the discharge channel by a strong radial magnetic field, causing a strong axial electric field to concentrate in this region.
4. This electric field heats the electrons, which subsequently ionize gaseous propellant (xenon) emitted near the anode.
6. The ionized gas accelerates axially through the electric field in the discharge channel, exiting the device at high speed, thus producing thrust.



AFRL IHPRPT Goals



In-House Research Resources

Advanced Hall Thruster Development

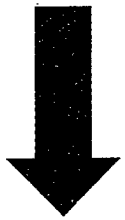
In-house FY00 budget request: $ 405,500

Currently FY00 funded Budget: $ 70,000 (17%)

Budgeted Man hours: 464 hrs

FY 98	FY 99	FY 00	FY 01*	FY 02*	FY 03**
0	139,000	70,000	339,000	348,000	335,000

* Projected Budgets
** Program End Date



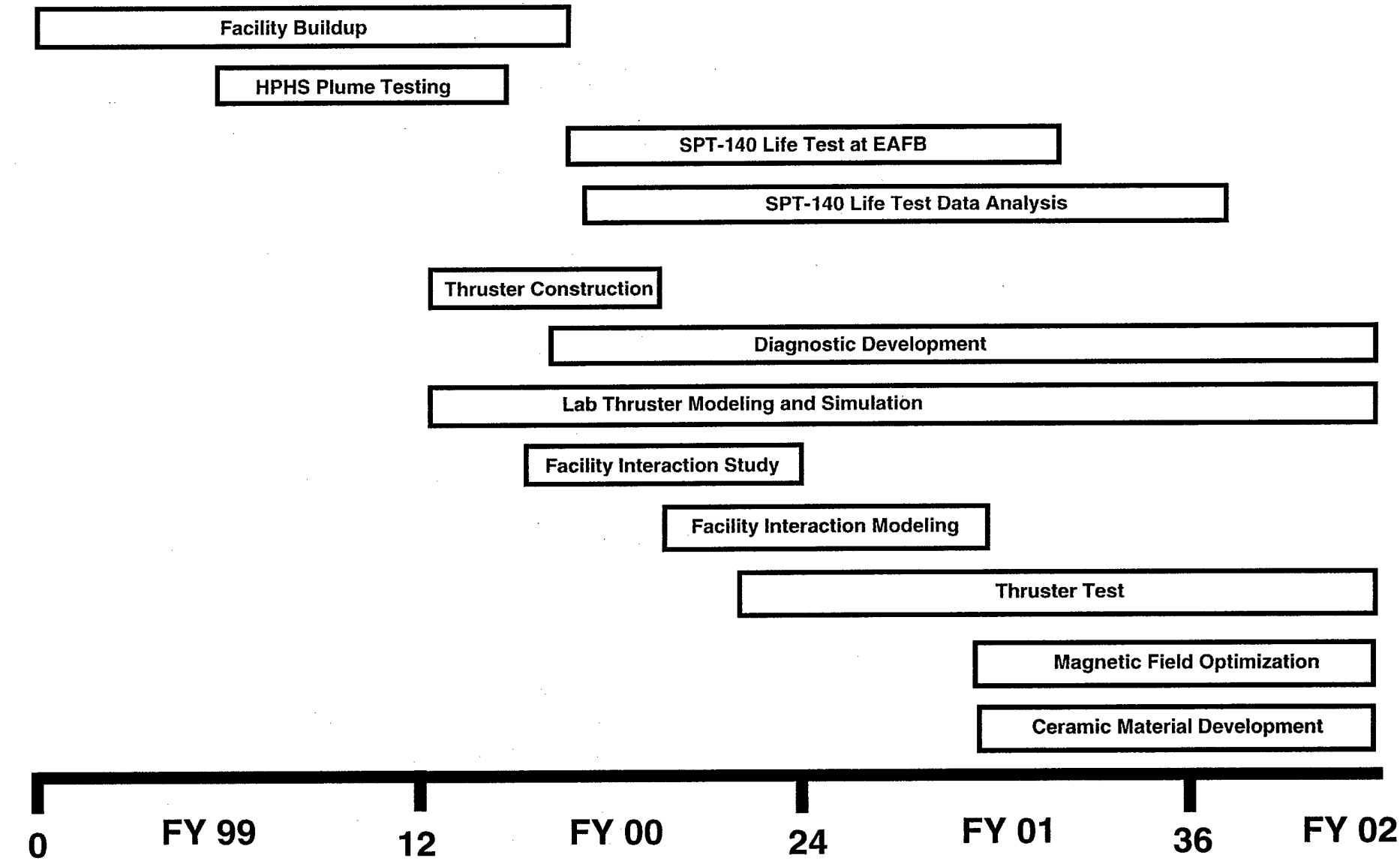
Funding Supports

- In-house research and development: 1 researcher, 1 mechanic
- Vacuum test facility upgrades and maintenance

AFRL In-House Research

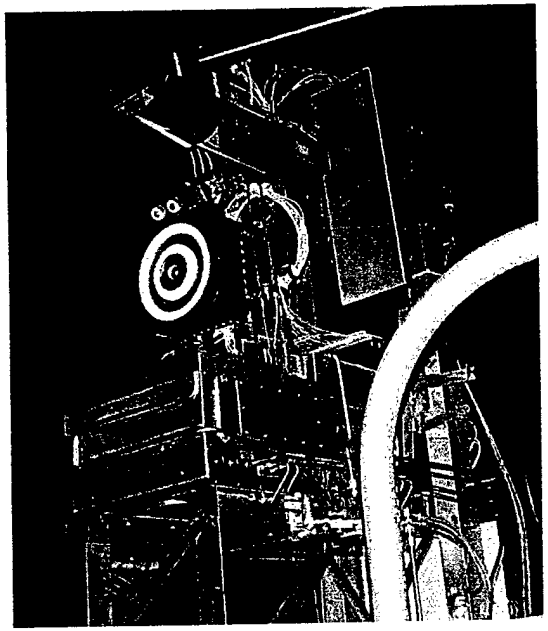
- High Performance Hall System Program
  - Space qualification of a 4.5 kW SPT-140 Hall thruster
  - AF Plume tests performed at NASA GRC, Univ. of Michigan
  - 7200 hour life test at AFRL starting March 2000
- Advanced Hall Thruster Development Program
  - Plasma diagnostic development
  - Construction of 5 kW laboratory thruster
  - Quantify thruster-facility interactions
  - Modeling and simulation
- Research Collaborations
  - AFOSR university research programs
    - Michigan
    - Stanford
    - Princeton
    - MIT

AFRL Electric Propulsion Road Map



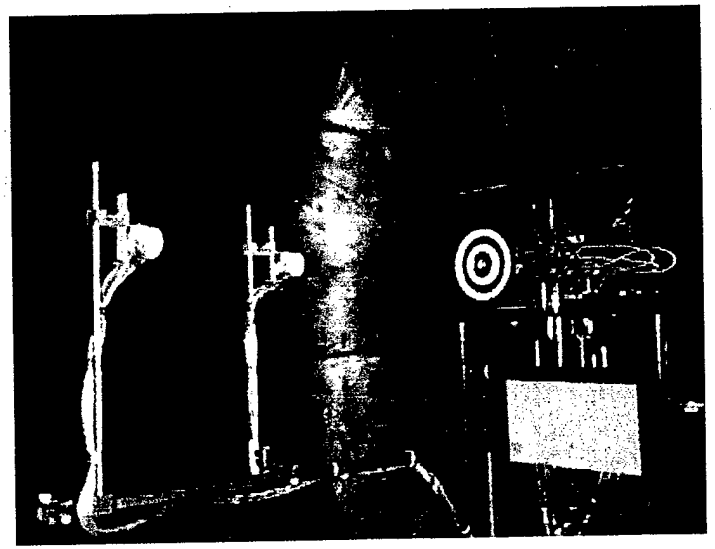
AF Ground Testing for the 4.5 kW Hall Thruster

NASA - Glenn
Chamber #6
25' dia x 60 ' long
500,000 l/s on Xenon



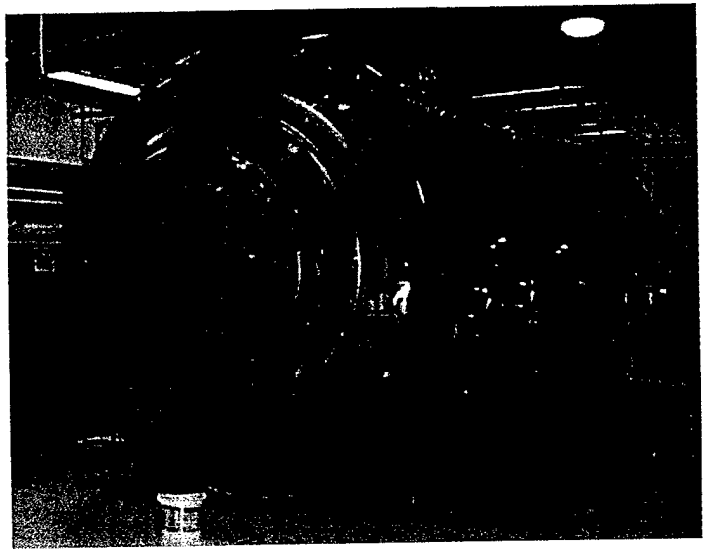
- Performance
- Current density
- EMI measurements
- Plume contamination

University of Michigan
20' dia x 30' long
140,000 l/s on Xenon



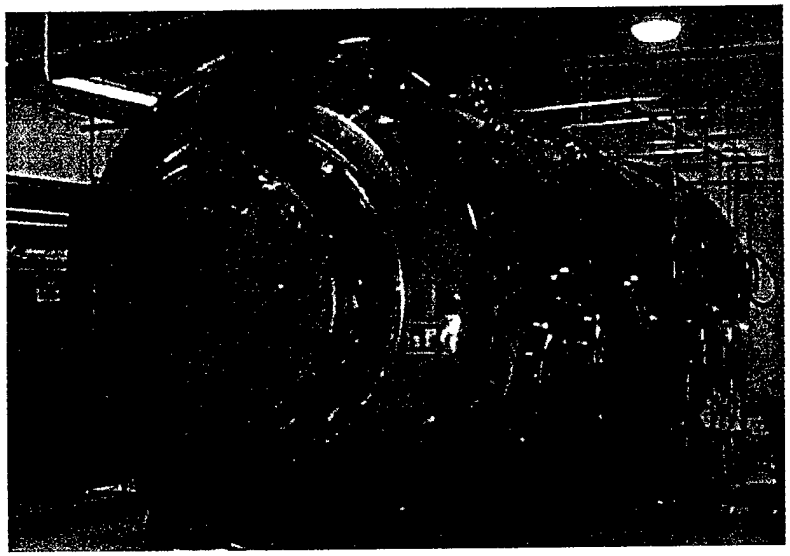
- Mass Spectrometry
- Current density

AFRL - EP Lab
Chamber #3
10' dia x 20' long
350,000 l/s on Xenon



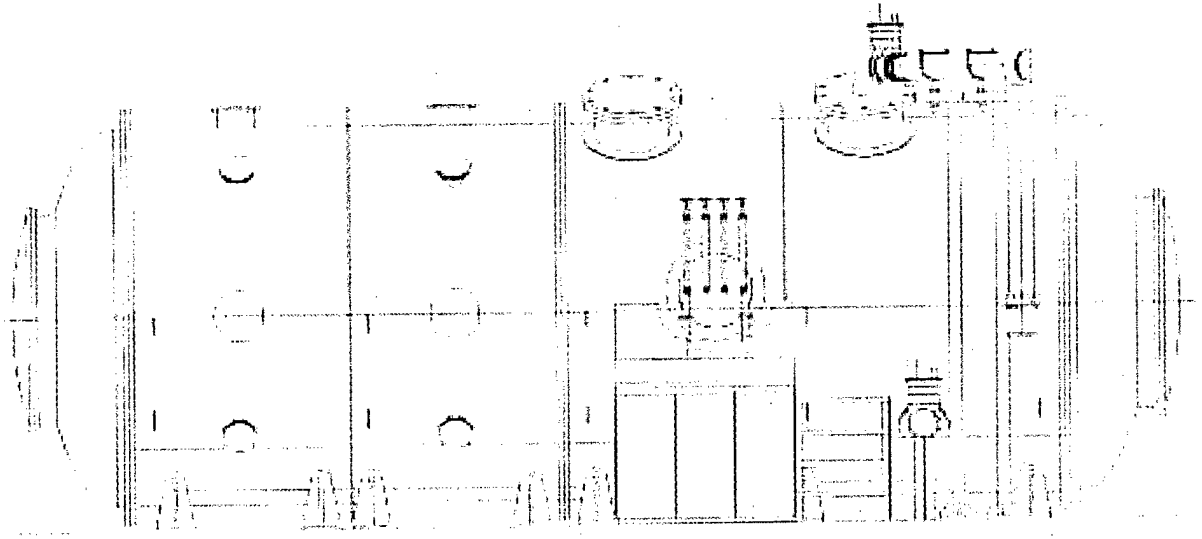
- Life Test (Performance)
  - 7200 Hours, 14 Months
- Plume Divergence
- Insulator Erosion Measurements

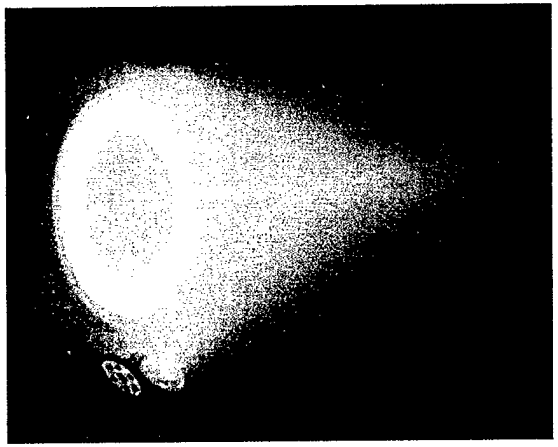
High Power Hall Thruster Life Test Vacuum Facility



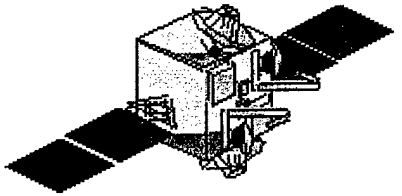
- 3 m diameter, 10 m length
- 350,000 l/s pumping speed (xenon)
- Construction complete Jan. 2000

- 7200 hour test begins March 2000, ends May 2001





4.5 kW Hall System Tech Transition Opportunity



MILSATCOM Advanced EHF

- Next Milstar system
- Approved extended duration orbit transfer
- Hall system supports NSSK and orbit raising
- #5 AF Space Command Near-Term Priority
- FY06 anticipated launch
- Aerospace Corp. SPT-140 evaluation

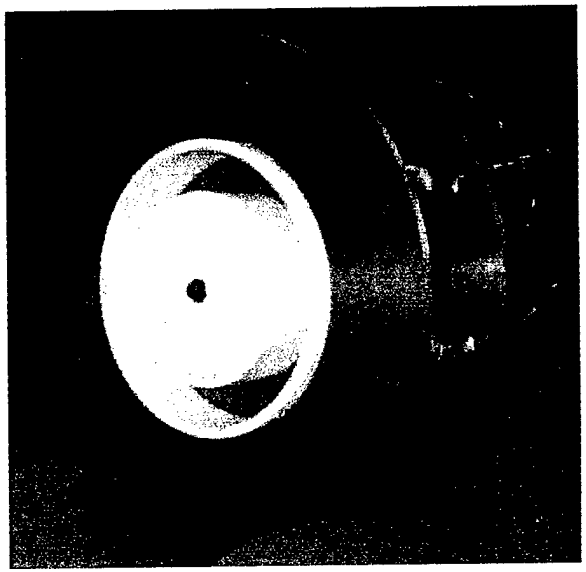
The Hall Thruster has a Technological Maturity sufficient to transition to commercial sector based on ground test data.

- Over 100 Russian flight thrusters decreases perceived risk

AFRL Advanced Hall Thruster Development

Laboratory Hall Thruster Development

- 5 kW laboratory Hall thruster with diagnostic access
- Jointly developed at AFRL with Univ. of Michigan
- Lower density improves survivability of probes
- Trend toward higher power thrusters
- Model thruster for other Laboratories / Institutions



Follow on Hall Thruster Development

- Magnetic field characterization and modeling
- Improved ceramic materials
- Improved power processing
- Alternate thruster geometries

Technical Challenges

- Thruster facility interactions
- Small thrusters poor diagnostic access

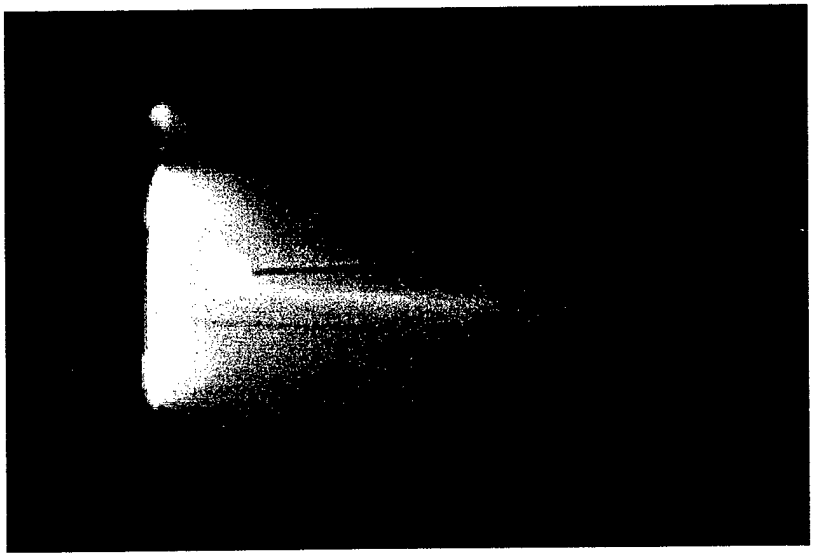
Approaches

- Construct model thruster
- Larger thruster

Hall Thruster Diagnostic Development

Electrostatic Probe Development

- Fast reciprocating probes
- Measurements
  - electron number density
  - electron temperature
  - plasma potential
  - electric field



Other Diagnostics

- Time of flight mass spectroscopy (TOFMS)
  - ion flux
  - ion energy
- High frequency microwave interferometry
  - electron number density
- Magnetic field characterization

Technical Challenges

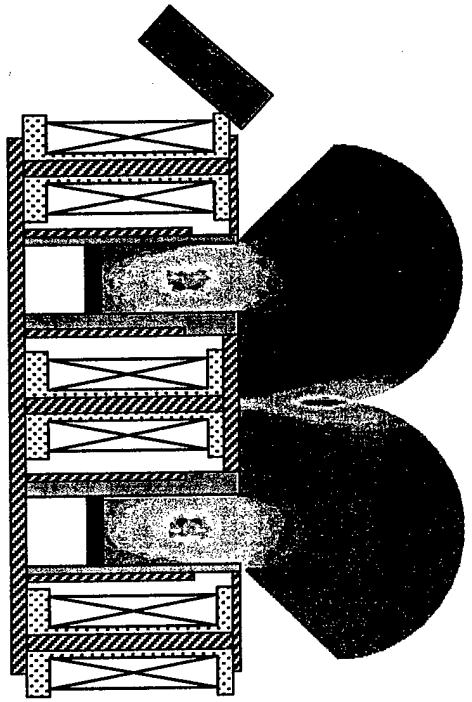
- Probe ablation within thruster
- Perturbation of plasma parameters

Approaches

- Construct fast reciprocating probe
- Larger thruster

Modeling and Simulation

Phase III Hall Thrusters: 30 kW to 60 kW for Orbit Transfer Missions
Critical Problem: Ground Test Facilities can dominate R&D costs (>$20M)
Solution: Understand physics of background gas ingestion



2D Hybrid-PIC Hall Code
Plasma Density Contours

2-D Hybrid PIC Code

- Models Physics of Accel. Channel and Near-Plume

3-D PIC-DSMC Plume Code

- Comprehensive Model for Plume Dispersion and Effects

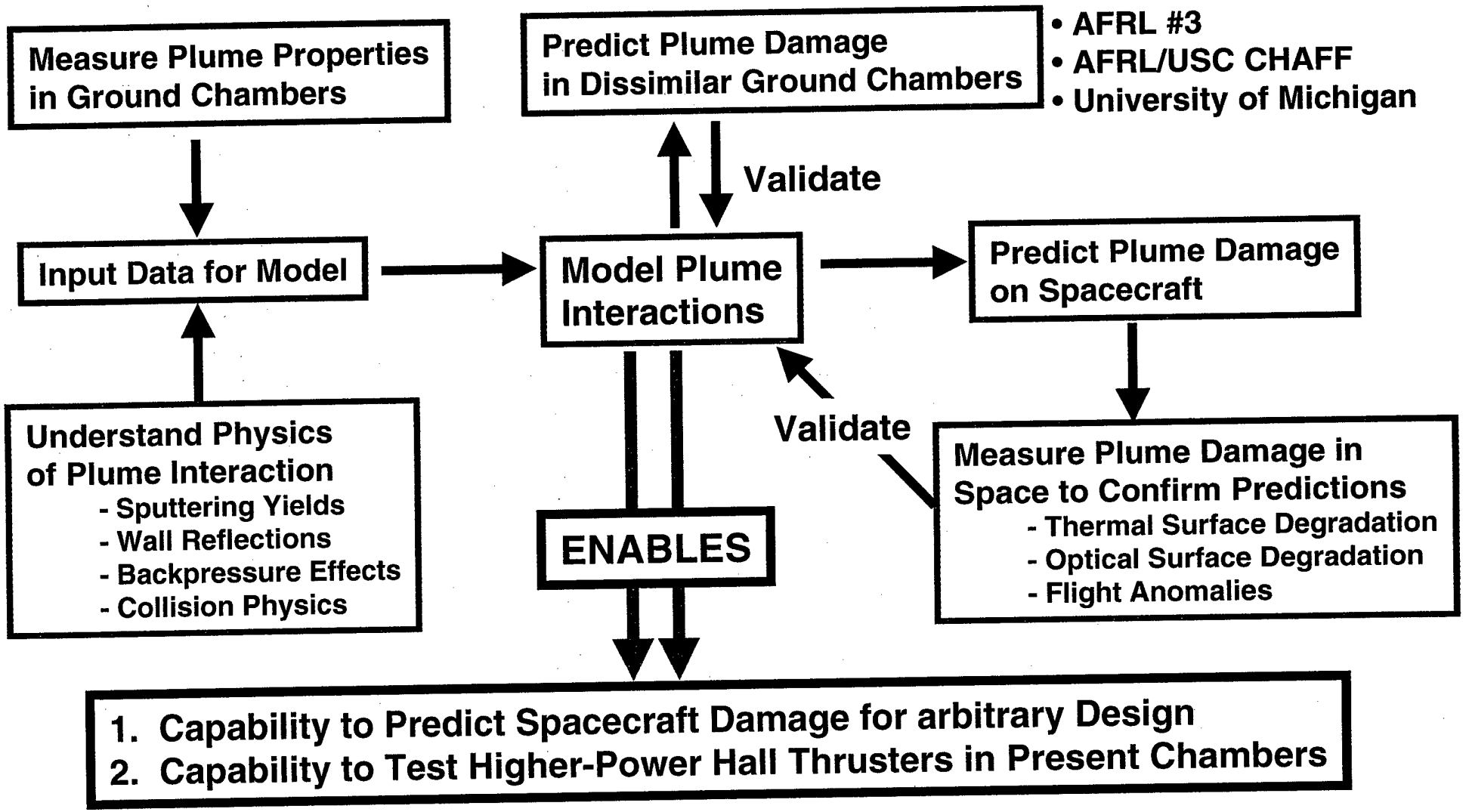
Team:

AFRL (AFOSR)
MIT (AFOSR)
LLNL (DOE)
Aerospace, AFRL/VS

4.5 kW Hall Lifetest Data, Modeling
Facility Interaction Theory & Modeling
Improvements to DSMC, PIC techniques
Xenon Collision Physics

Develop correction technique for backpressure at high propellant flow.
Test Higher Power Hall Thrusters in Existing Chambers

AF Modeling Needs for Electric Propulsion



Must balance COST vs. RISK REDUCTION at each step

Summary of Air Force Hall Thruster Development

- High Performance Hall System
  - Life test of SPT-140 for space qualification
  - Achieve Phase I goals (20% improvement)
  - Transition to customer
- Advanced Hall Thruster Development
  - Laboratory Hall thruster
  - Diagnostic development
  - Modeling and simulation
  - Achieve Phase II goals (35% improvement)
- Preparation for Phase III goals
  - Very high power laboratory Hall thruster development
  - Thruster-facility interaction
  - Increased modeling and simulation
- Collaboration with research institutions
  - AFOSR university research programs